STRATIGRAPHY OF URUK SULCUS AS REVEALED BY HIGH-RESOLUTION GALILEO IMAGES,
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Introduction. During its first orbit, the Galileo spacecraft obtained the first high resolution images of grooved terrain in Uruk Sulcus on Ganymede [1]. These data have allowed us to examine stratigraphic relations, providing a basis to evaluate processes in the formation and evolution of part of this geologically complex area [2]. Our analysis has resulted in the production of a map of different terrain types (Figure 1). The units are similar to those defined in geologic or geomorphologic mapping, allowing three dimensional relationships to be assessed, but differ from traditional planetary mapping [3,4] in terms of the use of structural characteristics in their definition along with the likelihood that many units do not represent actual material units.

Unit Characterization: On the basis of surface morphology and cross-cutting relations, nine units (Figure 1) have been identified in the part of Uruk Sulcus imaged by Galileo. The most abundant unit, **Parallel Ridged Terrain (PRT)** contains abundant, greater than 4-5 km, elongate (5-40 km) parallel ridges that commonly have two wavelengths of ridge spacing. The more widely spaced ridges range from about 500-1500 m apart and appear triangular in cross section. The more closely spaced ridges are 200-800 m apart and are typically less continuous along their lengths. PRT occurs mainly in two wide belts oriented about N40W. A western belt (PRT1) is about 20-25 km wide while an eastern belt (PRT2) is about 20-38 km wide and tapers to the south where it abuts the En Echelon Ridged Terrain (EERT). Additional occurrence of PRT lie along the western and eastern margins of the mapped area (PRT3-4), the latter of which has a north-south orientation of ridges. The edges of these zones are marked by steep linear scarps that are interpreted to be normal faults. **Parallel Ridged Terrain in Spindle-Shaped Occurrence (PRTS**) contains ridges similar to those seen in the PRT but differs in its outcrop pattern. Instead of a long zone of consistent width, it has a 'spindle' shape with ridges tapering toward both ends. There is only one occurrence of PRTS which is located in the SE part of the map area where it is bounded to the north by EERT to the south by ST2 and PRT4 and appears to cut the latter unit. Formation of PRTS is interpreted to be associated with partial extension and shear and it appears to be a transtensional fault duplex related to EERT. **En Echelon Ridged Terrain (EERT)** is characterized by a series of ridges of variable width and spacing (~300-1400 m) with lengths of a few up to 10 km which are arranged in an en echelon pattern. These ridges are arrayed between two bounding inward facing scarps separated by 5-10 km and strike across the region with an orientation of about N60W. A broad ridge and scarp are present in the middle of this unit. To the west, these structures are cut by smaller ridges. The linear nature of this feature, the angled en echelon pattern and the relation of this unit to surrounding units, suggest the presence of shear with right-lateral motion. **Striated Terrain (ST)** is composed of ridges that are typically less than 500 m across. In some places the ridges show slight angular relationships that locally give the terrain a rhomboidal pattern. This unit is distinguished by a variable crater density. Three major occurrences of ST are identified. ST1 forms a large block about 25 km wide and about 45 km long in the NW part of the map area. ST1 is cut to the east and west by PRT and to the south by EERT. ST2 is a 13 km wide, 25 km long block whose linear texture is oriented N-S. ST3 is a small patch exposed along the eastern portion of the mapped area. The ridges in this unit are similar to the small ridges in PRT and thus are interpreted to have formed by normal faulting and rotation of tilted fault blocks. **Braided Terrain (BT)** occurs as a linear wedge about 4 km wide which flares out to about 11 km wide at its northern end. The texture of this unit is distinctly braided, made up of narrow ridges a few hundred meters wide and 3-5 km in length. The unit occurs only locally at the base of a large scarp at the edge of a region of PLT to the west and EERT to the north. To the east it is bounded by ST2. Ridges of this unit along the base of the western scarp appear to be tilted fault blocks. **Cuspate Ridged Terrain (CRT)** is characterized by relatively large, wide ridges (several hundreds of meters to over a km) which are arranged in an arcuate or cuspate form. There are two occurrences, each forming a triangular unit adjacent to the EERT (CRT1 and CRT2). These two units appear to be related to the shear zone and splaying of faults. The unit of **Pitted and Lineated Terrain (PLT)** is distinguished by the presence of abundant pits of a variety of sizes and shapes along with sets of subdued striations and ridges. The surface appears regionally to be relatively flat and is dissected by troughs or grooves. Unlike most other units, a considerable number of the pits (more in PLT2 than PLT1) are cut by troughs and thus predate these more through going structures. There are two occurrences of PLT, an angular 25 km wide block in the south (PLT1) which has very subdued linear features that trend N-S, and a large block with linear features that trends N55E (PLT2). In PLT2, some of the pits are cut by linear structures while others are superposed on linear structures. A large, arcuate feature at the edge of this unit may be an old impact crater that is dissected by structure within the PLT which is in turn cut and partly destroyed by ridge formation in PRT2. The pits in this unit are interpreted to be impact craters, many of which are degraded. PLT1 appears qualitatively to be more heavily cratered than PLT2. At least some of the impact craters in PLT2 predate some of the deformation forming the ridges. These units appear to be the oldest in the area from both a crater density and stratigraphic point of view. The **Parallel Mesa and Ridged Terrain (PMRT)** unit has two components; the most distinctive of which is the occurrence of linear, parallel flat top mesas that are up to 2-3 km wide and 20-30 km long. The second component is made up of relatively narrow parallel ridges similar to those seen in PRT and ST. The unit has two major occurrences; PMRT1 in which the linear features are oriented N35E and PMRT2 in which the features are oriented approximately N-S. In PMRT1, the unit appears to be forming at the expense of the adjacent PLT2. PMRT1 is interpreted to have formed from tilted fault blocks (ridges) in the eastern part and horsts (mesas) and graben in the western part. A third, minor occurrence (PMRT3) is located in the SW part of the map area. A variety of **craters (C)** are found in this region, the largest of which has a diameter of ~7.5 km and possesses a hummocky floor and a dark eastern interior with

an adjacent 5 km wide and 8 km long dark patch. The large crater is superposed on PRT2, but some of the structural elements appear to cross the crater floor. One of the remarkable aspects of the crater is the apparent lack of extensive ejecta in the rim area (except for the dark material). There is some hint of possible ejecta lobes to the north, but generally evidence for the emplacement of ejecta at the scale that would modify the surrounding ridges is absent. The presence of a dark deposit adjacent to this crater could be interpreted to suggest that the impactor has excavated dark material which lies below the bright terrain (e.g., Schenk and McKinnon, 1985 [5]). In this case the dark material would probably lie at a depth of several hundred meters.

Geological History: On the basis of asssessing the characteristics of the different terrain types and examining their spatial relationships, we outline the following geological history for the region of Uruk Sulcus imaged by Galileo. The youngest units in the area are PRT1, PRT2, and EERT which are interpreted to have formed nearly contemporaneously. The CRT unit may have also formed at this time as a result of shear along the margins of PRT1/EERT/PRT2, and the PRTS unit appears to be a fault duplex which also formed in association with large-scale lateral motion. Units of intermediate age include PMRT1-2 as well as ST1-3, and BT. Occurrences of ST1-3 do not appear as heavily cratered as the stratigraphically older PLT. This suggests that some sort of resurfacing has obliterated the impact craters that were previously on this surface. The stratigraphically oldest and qualitatively most heavily cratered units are PLT1 and PLT2. This is particularly well displayed in the northern part of the area, where normal faults can be seen to cut both a 5 km crater and orthogonal linear structures in the adjacent Pitted and Lineated Unit (PLT2). Splays of this normal fault then merge into the ridges in the adjacent PRT. Additional evidence is seen at the northeastern boundary of PRT1 (SW part of the map area). Here, some of the linear texture of Cuspate Ridged Unit 1 can be seen to extend into the PRT1 and to be successively cut by normal faults until it is no longer visible. The most prominent ridges in the CRT1 project into the PRT1, but are dissected by the linear structure of PRT1 into broad knobs. Less prominent ridges that extend from CRT1 into PRT1 are preserved as small knobs, but the linear texture of PRT1 dominates. Further to the south, where the Pitted and Lineated Terrain is cut by PRT1, the ridges in the PLT are so subdued that there is little to no evidence of them extending into CRT1. These relationships suggest that the terrain adjacent to the present CRT has been destroyed by imbricate normal faulting to form PRT, and that the formational process is completely destroying evidence of the preexisting terrain in a type of 'tectonic resurfacing [6].'

References: [1] Belton, M.J.S., et al., *Scienc*e, 377-385,274, 1996. [2] Squyres, S., *Icarus 46*, 156, 1981 [3] Wilhelms, D.E., *U.S.G.S. Prof. Paper 599-F*, F1-F47, 1970. [4] Wilhelms, D.E., *USGS Interagency Report: Astrogeology 55*, 36p., 1972. [5] Schenk, P. M., and W. B. McKinnon, Proc. LPSC 14, in *J. Geophys. Res*., 90, C775-C783, 1985. [6] Head, J. W. et al., LPSC XXVIII, this volume, 1997.

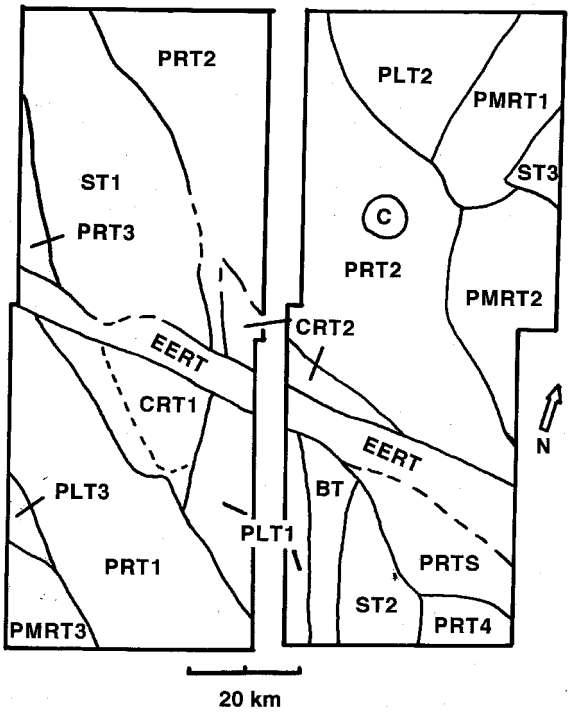

FIGURE 1. Terrain unit map of a section of Uruk Sulcus based on Galileo high resolution images (~74 m/pixel).